3

201-524

A

SELECTIVE POLARIZATION MATCHING FILTER FOR TRIGGERING AND MAXIMIZING RAPID DIELECTROKINESIS RESPONSE

BACKGROUND OF THE INVENTION

This invention relates to the fields of dielectrokinesis (phoresis), dielectric relaxation dynamics, electronic devices and systems and, more particularly, to a selective polarization matching filter for triggering and maximizing the dielectrokinesis response in the detection of specific entities consisting of organic and inorganic materials via detection of a force or replenishment energy density of stored electrical energy.

The detection of the presence or absence of specific entities -- human beings, plastics (mixtures of various polymers and with additives) and other organic/inorganic materials -- irrespective of the presence of intervening vision-obstructing structures or EMI signals has uses in very diverse applications such as: (a) fire fighting and rescue; (b) national border security; (c) transportation security in pre-boarding planes, trains and automobiles; (d) new and old construction industry; (e) law enforcement; (f) military operations; (g) anti-shoplifting protection; (h) other security and emergency needs and operations, etc.

It is known that humans, animals and other animate species generate an external electric field and gradients thereof. For example, in human physiology, the central and peripheral nervous system neurons, the sensory system cells, the skeletal muscular system, as well as the cardiac conduction cells and cardiac muscle system cells all operate by a depolarization and repolarization phenomena occurring across their respective cellular membranes, which are naturally in a dielectric polarization state.

2

The trans-membrane ion currents and potentials utilizing Na^{+1}, K^{+1} ions, etc., all work to establish a resting potential across the cell membranes that can be characterized as a high state of polarization. The ion concentration (moles/cm^3) within and surrounding the unmyelinated cell axon establish the resting potential. The fluids themselves are neutral. What keeps the ions on the membrane is their attraction for each other across the membrane. Independent of this process the Cl^{-1} ions tend to diffuse into the cell since their concentration outside is higher. Both the K^{+1} and Cl^{-1} diffusion tend to charge the interior of the cell negatively and the exterior of the cell positively. As charge accumulates on the membrane surface, it becomes increasingly difficult for more ions to diffuse. K^{+1} ions trying to move outward are repelled by the positive charge already present. Equilibrium is reached when the tendency to diffuse because of the concentration is balanced by the electrical potential difference across the membrane. The greater the concentration difference, the greater the potential difference across the membrane. The resting potential can be calculated by the Nernst Equation, wherein the potential (V)=V_{Inside}-$V_{Outside}$ such that:

$$Voltage(potential) = 2.30\frac{kT}{ze}\log\frac{Co}{Ci}$$

where Co and Ci are ion concentrations inside and outside, k is the Boltzmann constant, T is absolute temperature, e is the charge on the electron and z is the valence (number of electron charges) on the ion.

The nerve and conduction impulses, as well as the sensory, cardiac, and muscular action potentials and subsequent responses are manifested via sequential periodic pulses (waves) resulting in first rapid depolarization and, shortly after, rapid repolarization to reestablish the rest state, namely, the original polarization state of the membrane. The transverse membrane ion currents produce a dipole

charge that moves along the cell membrane. The greater the stimulus the more the pulses that are produced along the membrane.

The action potentials are related to the ratio of the respective ion concentrations inside and outside the different types of membranes. The resultant polarization electrical field distribution pattern has a high degree of spatial non-uniformity and can be characterized as a bound dipolar charge distribution pattern. A detailed discussion of the human generated electric field can be found in R.A. Rhodes, *Human Physiology,* Harcourt Brace Javanovich (1992) and D.C. Gianocoli, *Physics Principles with Applications,* Prentice Hall (1980), the teachings of which are hereby incorporated by reference.

Alternatively, the external electric field and gradients thereof can be supplied by an external source via static electrification for use with inanimate targets such as plastics, metals, water, etc.

It would be advantageous to be able to detect the external electric field and gradients thereof, either generated naturally by an animate species or induced by an external source, on an entity specific basis. It would further be advantageous to enable this detection at great distances and through obstructions. It has been discovered that such detection is possible using the selective polarization matching filter in accordance with the present invention in conjunction with the principles of dielectrophoresis.

Dielectrophoresis describes the force upon and mechanical behavior of initially neutral matter that is dielectric polarization charged via induction by external spatially non-uniformity electric fields. The severity of the spatial non-uniformity of the electric field is measured by the spatial gradient (spatial rate of change) of the electric field. A fundamental operating principle of the

dielectrophoresis effect is that the force (or torque) in air generated at a point and space in time always points (or seeks to point) in the same direction, mainly toward the maximum gradient (non-uniformity) of the local electric field, independent of sign (+ or -) and time variations (DC or AC) of electrical fields (voltages) and of the surrounding medium dielectric properties.

The dielectrophoresis force magnitude depends distinctively nonlinearly upon the dielectric polarizibility of the surrounding medium, the dielectric polarizibility of initially neutral matter and nonlinearly upon the neutral matter's geometry. This dependance is via the Clausius-Mossotti function, well-known from polarizibility studies in solid state physics. The dielectrophoresis force depends nonlinearly upon the local applied electric field produced by the target. The dielectrophoresis force depends upon the spatial gradient of the square (second power) of the target's local electric field distribution at a point in space and time where a detector is located. The spatial gradient of the square of the local electric field is measured by the dielectrophoresis force produced by the induced polarization charge on the detector. This constant-direction-seeking force is highly variable in magnitude both as a function of angular position (at fixed radial distance from the target) and as a function of the radial position (at a fixed angular position) and as a function of the "effective" medium polarizibility. The force's detection signature is a unique pattern of the target's spatial gradient of the local electric field squared, with the detector always pointing (seeking to point) out the direction of the local maximum of the gradient pattern. All experimental results and equations of dielectrophoresis are consistent with the fundamental electromagnetic laws (Maxwell's equations).

There are five known modes of dielectric polarization. These include: electronic polarization, where electron distribution about the atom nuclei is slightly distorted due to the imposed external electric field; atomic polarization,

where the atom's distribution within initially neutral matter is slightly distorted due to the imposed external electric field; nomadic polarization, where in very specific polymers, etc., highly delocalized electron or proton distribution is highly distorted over several molecular repeat units due to the imposed external electric field; rotational polarization (dipolar and orientational), where permanent dipoles (H_2O, NO, HF) and orientable pendant polar groups (-OH, -Cl, -CN, $-NO_2$) hung flexibly on molecules in material are rotationally aligned toward the external electric field with characteristic time constants; and interfacial (space charge) polarization, where inhomogeneous dielectric interfaces accumulate charge carriers due to differing small electrical conductivities. With the interfacial polarization, the resulting space charge accumulated to neutralize the interface charges distorts the external electric field with characteristic time constants.

The first three modes of dielectric polarization, electronic, atomic and nomadic, are molecular in distance scale and occur "instantaneously" as soon as the external electric field is imposed and contribute to the dielectric constant of the material at very high frequencies (infrared and optical). The last two polarization modes, rotational and interfacial, are molecular and macroscopic in distance scale and appear dynamically over time with characteristic time constants to change (usually increase) the high frequency dielectric response constant toward the dielectric constant at zero frequency. These characteristic material time constants control the dielectric and mechanical response of a material.

The modes of polarization and their dynamics in contributing to the time evolution of dielectric constants are discussed in various publications, such as H.A. Pohl, *Dielectrophoresis*, Cambridge University Press (1978); R. Schiller *Electrons in Dielectric Media*, C. Ferradini, J. Gerin (eds.), CRC Press (1991), and R. Schiller, *Macroscopic Friction and Dielectric Relaxation*, IEEE

Transactions on Electrical Insulation, 24, 199 (1989), the well-known teachings of which are hereby incorporated by reference.

SUMMARY OF THE INVENTION

The present invention relates to a selective polarization matching filter formed of compositions of matter using initially neutral material chosen to be an exact dielectric replicate of an entity to be detected via dielectrokinesis (phoresis). The filter is an essential element in triggering and also maximizing both the mechanical torque and energy replenishment modes using dielectrokinesis (phoresis) methods to detect entities.

This filtering action applies to a practically limitless range of materials to be detected as an entity of interest target. The detection materials include, for example, nano-structured human keratin protein polymer for human detection, nano-structured animal keratin protein polymer for animal detection, specific plastic (mixture of polymers and additives) for plastic detection, and the like. The dielectric replicate material comprising the selective polarization filter functionally performs a spatial dielectric property matching between the entity of interest and a locator device to locate the entities. The filter enables the device to operate using the dielectrokinesis (phoresis) phenomena to specifically detect only those entities matching the dielectric response signature of the polarization filter component. The dielectric signature includes both the dielectric constant and dielectric loss frequency spectra and all characteristic time constants controlling the polarization evolution/mechanics in external electric fields.

There are two primary elements for the dielectrokinesis entity location detection device to operate. The first element is an external electric field and spatial gradients thereof, and the second element is the selective dielectric polarization matching filter of the present invention. As noted above, the external

electric field and gradients thereof can be provided by the entity of interest itself as is the case when animate species are the entities of interest to be detected. Alternatively, the external electric field and gradients thereof can be supplied by an external source via static electrification as is the case when inanimate entities are the entities of interest to be detected.

The selective polarization matching filter embodied in this invention can be used in the detection device itself as either a passive or active circuit component (no flowing or flowing continuous electric current, respectively). The selective polarization matching filter embodied in this invention can be used with conventional electronic components (resistors, capacitors, inductors, transistors, etc.) in the overall operational design of the type of locator device used to detect the presence or absence of a specific entity of a predetermined type.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages and objects of the present invention will be described in detail with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic illustration of a first embodiment selective polarization matching filter according to the present invention;

FIGURE 2 is a schematic illustration of a second embodiment selective polarization matching filter according to the present invention;

FIGURE 3 is a schematic illustration of a third embodiment selective polarization matching filter according to the present invention; and

FIGURE 4 illustrates an auxiliary attachment used in accordance with the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The external electric field and gradients thereof of the target entity defines a specific polarization pattern for the entity. In order to detect the target entity electric field and gradients thereof, it is necessary to impart an opposite polarization pattern on a detector element such as an antenna or the like. The selective polarization matching filter according to the present invention serves as a matching bridge between the detector operator and the opposite polarized detector component to generate the opposite polarization pattern.

It has been discovered that specific combinations of materials provide the desired effects of the selective polarization filter. FIGURE 1 illustrates the filter according to a first embodiment of the invention for non-electrically conducting materials. As shown in FIGURE 1, the filter 10 includes a replicate dielectric property matching material 12 encapsulated within a filter body 14 formed of a polymer such as polyurethane. A pair of parallel plates 16 disposed enclosing the replicate dielectric property matching material 12 are also encapsulated in the filter housing 14. The plates 16 are preferably formed of a different polymer such as acrylonitrile-butadiene-styrene (ABS). In this arrangement, the plates 16 are coupled with metal electrical leads 20 via isocyanate glue pods 18 or the like.

The replicate dielectric property matching material 12 is selected in accordance with the characteristics of the entity to be detected. That is, the replicate property matching material contains identical dielectric properties, time constants and related macroscopic friction coefficients to those of the entity material to be detected. Examples of suitable replicate dielectric property matching materials include nano-structured human keratin protein polymer for human detection, nano-structured animal keratin protein polymer for animal detection, specific plastic (mixture of polymers and additives) for plastic detection and the like.

With reference to FIGURE 2, in a second embodiment for electrically conducting replicate materials, the structure is substantially similar to that of the first embodiment. The plates 16' in the filter 10', however, are formed of metal such as copper, brass, aluminum or steel. The metal plates 16' are connected to the electrical leads 20' via solder pods 18'. Examples of suitable conducting replicate property matching materials include, for example, gold, silver, platinum, palladium and iron.

In a third embodiment, referring to FIGURE 3, for non-electrically conducting replicate materials, the replicate dielectric property matching material itself is utilized as the filter housing. As shown in FIGURE 3, the filter 30 according to the third embodiment of the invention includes a filter housing 32 formed of the replicate dielectric property matching material and defining therein a cavity 34. Another dielectric material 36 such as air is disposed in the cavity 34. Exit ports 38 from the cavity 34 are formed in the filter housing 32 and are filled with a conducting material 40, preferably of metal, coupled with an external electronic circuit connector and grounding terminals (not shown).

It has been discovered that the effects of the selective polarization matching filter according to the invention can be enhanced with the application of an auxiliary attachment 50. The auxiliary attachment 50 contains a solution of 2-propanol or a solid or liquid of 2-methyl-2-propanol contained within a plastic housing 52 as shown in FIGURE 4. The attachment 50 includes a conducting bar 54 in contact with the propanol or 2-methyl-2-propanol coupled with a wire lead 56 that extends to the exterior of the housing 52. In operation, the auxiliary attachment 50 operatively cooperates with the filter according to the present invention to provide the enhanced effects.

The dielectrokinesis(phoresis) phenomena can be used with the current dielectric polarization matching filter disclosure of the invention in at least two methodologies to enable the detection and location of specific entities of interest. The first methodology utilizes the dielectrophoresis force directly. This is usually observed via a torque "action at a distance" motion acting around a well-defined pivot point and line. An example of this application is described in commonly owned, ~~co-pending~~ U.S. patent ~~application serial~~ number ~~08/758,248;~~ 5,748,088 the disclosure of which is hereby incorporated by reference.

TV 12/29/98

The second methodology is where a dielectric replicate of the material of interest to be detected is provided with an external electric field and spatial gradients thereof by external static electrification. This allows a measurable electrical energy replenishment to occur when a second material, dielectrically matching the replicate reference material, comes within close proximity to the reference material and undergoes polarization by the external electric field provided by the static electrification.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

11